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ABSTRACT

Two-thirds of what we waste could be reused without important changes in our life-styles. One benefit of recycling would be the diminishing contribution of raw materials prices to inflation. For a sustainable resource policy there are three basic components: waste reduction, waste separation, and waste recovery. The first can be met by producing more durable goods, banning non-refillable containers, increasing charges for pick-up and disposal of waste, designing products which are easy and economical to repair, and ending discriminatory taxes and regulation. Separation of waste in homes and disposal units will facilitate recycling of paper, aluminum, glass, metals, and even plastics, though there are attendant problems of cost and social acceptance. Energy can be produced from waste when valuable materials are removed through chemical and physical processes. The possible impact of future mineral cartels such as the Organization of Petroleum Exporting Countries (OPEC) could be reduced through recycling. The amount of energy saved by recycling compared with that expanded on processing virgin materials ranges from eight to 95%. To go from conspicuous consumption to conspicuous frugality specific policies and social commitment are necessary. In this regard the public may be ahead of its leaders. (Author/DL)



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# Repairs, Reuse, Recycling— First Steps Toward a Sustainable Society

Denis Hayes

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## Introduction

At least two-thirds of the material resources that we now waste could be reused without important changes in our life-styles. With products designed for durability and for ease of recycling, the waste streams of the industrial world could be reduced to small trickles. And with an intelligent materials policy, the portion of our resources that is irretrievably dissipated could eventually be reduced to almost zero.[1]

The ever-expanding consumption of both raw materials and energy has become an inflationary force that is likely to grow as high-grade ores are exhausted, as energy costs rise, and as the pollution control investments needed to safely process low-grade ore increase. A sensible materials policy—one that emphasized the repair, reuse, and recycling of goods we currently discard—would help check these inflationary pressures.

Most of what we use today is soon thrown away. About 70 percent of all metal is used just once and then discarded. The remaining 30 percent is recycled. After five cycles, only one-quarter of 1 percent of the metal remains in circulation. After ten cycles, less than one one-thousandth of 1 percent remains.[2]

Annual per capita mineral use worldwide is now more than 3.75 metric tons, and is increasing 7 percent each year. If continued, such growth

I am indebted to my colleague Christopher Flavin for his help with the research for this paper.

would lead to a 32-fold increase in mineral use in just 50 years. The highest rate of consumption is found in the industrial world; in the United States, the figure is 15 metric tons per person. The lifetime garbage of a typical American will equal at least 600 times his or her adult weight. Most of these minerals will make a one-way trip from the mine to the dump. But as high-grade ores are exhausted and dumps become overcrowded, we must increasingly turn to our wastes for our wealth.[3]

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Waste is a human concept. In nature, nothing is wasted, for everything is part of a continuous cycle. Even the death of a creature provides nutrients that will eventually be reincorporated in the chain of life. The idea of waste springs from the perception of most material by-products of human activity as useless. But one person's waste newspapers are another person's recyclable fibers or cellulose insulation. Disposable plastic containers that are discarded without thought by the Japanese would be carefully used and reused by Tanzanian villagers. The Japanese, in turn, are aggressive purchasers of scrapped U.S. automobiles, leading to the joke that this year's Buick is next year's Datsun. And the concept of waste varies over time. Much of what were thought of as the wastes of the pulp and paper industry some decades ago are now a source of fuel and chemical feedstocks. The designation "waste" is thus a product of judgment and circumstances.

Not much hard data exists about materials use in the Third World. However, the recycling system in Cairo illustrates the different understanding of "waste" in developing countries. Wastes from the eight million households are handled mostly by two groups in Cairo: the Wayiha, who control rights to the city's domestic refuse, and the Zabaline, who rent the right to do the actual removing and processing of Cairo's domestic waste. They remove tin, glass, paper, plastic, rags, and bones from the refuse, and forward these materials to factories and other markets within the city. They extract about 2,000 tons of paper a month that is reprocessed into some 1,500 tons of recycled paper and cardboard. Cotton and wool rags are converted into upholstery and blankets; metals are converted into new implements; even bones are used to make such things as glue, paints, and high-grade carbon for sugar refining. Most organic wastes are fed to pigs;

the rest is converted into compost that is sold for agricultural purposes. In societies with chronic unemployment, inefficient bureaucracies, and few raw materials, such labor-intensive, income-producing approaches make more sense than the capital-intensive, high-technologies favored by many Western-trained engineers.[4]



The term "consumption" is similarly ambiguous. A newspaper, for example, has been "consumed" when the purchaser has finished reading it. A product may be thought of as consumed when it has provided all the usefulness its owner expects from it. Thus a perfectly good pair of shoes, or even a perfectly functioning automobile, will be thought of as consumed if changing styles persuade the owner to discard the older product for something newer.

Modern economies are geared toward an endless increase in material consumption and the generation of ever-larger amounts of waste. Underlying this is an implicit policy to encourage the use of virgin materials. Many policies that were designed long ago for the protection of fledgling industries remain on the books, greatly distorting the materials market. The mining and extractive industries, for example, are given more favorable tax treatments than are industries based on the use of recycled materials. The full costs of environmental damage due to mining have not been internalized and hence the prices of virgin materials do not reflect the full social burdens their extraction imposes. Secondary materials are often discriminated against in government procurement specifications, freight transport tariffs, and so on.[5]

Moreover, the institutional structure does not adequately discourage the generation of waste. For example, the charge for waste pickup often remains constant regardless of how much garbage is produced. Waste disposal charges are often artificially low because the environmental costs of disposal have not been considered. Where efforts have been made to overcome these imbalances, significant progress has often been made. Some small New England towns are currently recycling about 50 percent of their wastes, and Wilton Falls, New Hampshire, has designed a recycling and composting program that the town planners expect to handle 80 percent of the town's wastes.

One hundred percent recycling will never be a genuine option. Rather than leaving materials in a concentrated form, much human activity dissipates them to an extent that sometimes approximates their average abundance in the earth's crust. Such uses, although often having merit in the short run, dramatically reduce the chance of successful recycling in the long run. For example, 50 percent of petrochemical feedstocks become commercial solvents, detergents, gasoline additives, antifreeze, dyes, pesticides, and pharmaceuticals—all of which are effectively lost as soon as they are used. The lead concentrated in storage batteries can be recycled easily; the tetraethyl lead added to motor gasoline is lost forever, except as a pollutant.[6]

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Society can minimize the extent to which materials are dissipated by use. For example, the substitution of ethanol—a high octane fuel obtainable from biological crops—for gasoline would eliminate the need for lead anti-knock additives. This, in turn, would remove the principal source of atmospheric lead (and the health problems it entails), simplify the recycling of lead, and convert motor vehicles to a fuel that will be available long after oil.[7]

In a sustainable world, what we currently think of as waste will become our major source of high-quality materials for industry and commerce. One important benefit will be the diminishing contribution of rising raw material prices to inflation. Increasingly, virgin ores will merely supplement the existing material inventory. Recycling will become a central organizing principle for the entire economy.

**Resource Supplies**

Stringent limitations on the production of several minerals from raw ores are unavoidable within the next half-century. For some, the turning point may be encountered far sooner. By the time this turning point is first reached, the world must have learned how to live comfortably with a finite, non-growing stock of the material in question.[8]

It is sometimes argued that since the entire planet is composed of minerals, the fear of running out of supplies is ridiculous. Such a notion rests upon a very loose definition of "supplies." All the min-

**"Resource estimates depend on a judgment of tomorrow's prices, tomorrow's technology, and tomorrow's supply of affordable energy."**

erals with which human civilization will be sustained are located in the four-tenths of 1 percent of the earth's mass constituting its outer crust. Of this, only a trifling fraction may be legitimately viewed as potential supplies. The remaining minerals are in such dilute concentrations or at such great depth in the crust that the energy and environmental costs of mining and concentrating them will always be prohibitive.



Broadly speaking, minerals can be grouped in two categories: "reserves" and "resources." Reserves are usually defined as known deposits that are extractable with existing technology at current prices. The term has great utility, but it must not be misused. As a case in point, Zambia has no copper reserves because that country's copper cannot be economically extracted at today's world price. Yet Zambia has some of the world's largest deposits of copper, much of which will be mined eventually.[9]

"Resources" is a much broader category that generally encompasses the total mineral base that can be extracted. Clearly, resource estimates also involve confusing uncertainties and depend on a judgment of tomorrow's prices, tomorrow's technology, and tomorrow's supply of affordable energy.

For particularly valuable mineral resources, reserves sometimes cover virtually all known resources. For example, to obtain three tons of diamonds from the world's richest diamond deposit, 75 million tons of rock had to be moved. Needless to say, the price charged for minerals obtained with such effort is very high. An entire economy cannot be built around minerals that cost as much as diamonds.

An average cubic kilometer of rock drawn from the earth's crust contains some 200 million metric tons of aluminum, 100 million metric tons of iron, 800,000 tons of zinc, and 200,000 tons of copper. But such figures are meaningless. The mineral producer is not interested in average rock, but in uncommon rock: ore that is disproportionately rich in one or more minerals and that can be economically extracted, transported, and refined. The average amount of lead in the continental crust, for example, is 0.001 percent, while lead ore generally contains between 2 and 20 percent lead.[10]

Twelve elements account for 99.23 percent of the mass of the earth's crust. (See Table 1.) Of these abundant elements, five are metals that are widely used in industry: aluminum, iron, magnesium, titanium, and manganese.

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**Table 1: Major Elements in the Continental Crust**

| Element | Amount by Weight |
|---|---|
| | (percent) |
| Oxygen | 45.20 |
| Silicon | 27.20 |
| Aluminum | 8.00 |
| Iron | 5.80 |
| Calcium | 5.06 |
| Magnesium | 2.77 |
| Sodium | 2.32 |
| Potassium | 1.68 |
| Titanium | 0.86 |
| Hydrogen | 0.14 |
| Manganese | 0.10 |
| Phosphorus | 0.10 |
| Total | 99.23 |

**Source:** Brian Skinner.

Most metals do not ordinarily appear in nature in their elemental states. They are combined with other elements in crystalline, inorganic compounds. To obtain these metals for human use, ores must be refined of nonmetallic impurities. The refining process, which involves the breaking down of stable compounds, is very energy-intensive. In order to minimize the energy needed for refining, the mineral industry prefers to use sulfides, oxides, hydroxides, and carbonates rather than the refractory silicate minerals that constitute most of the earth's crust.

For several years, interest has been growing in the mining of large deposits of manganese nodules from the ocean floor. These potato-sized nodules contain 25 to 30 percent manganese, and are also rich

sources of nickel, copper, and cobalt. There appear to be no insurmountable technical difficulties in mining them. Such activities, however, will be enormously expensive, requiring at least a doubling in copper prices and a 50 percent increase in nickel prices for economic operation. Deep-sea mining will also be energy-intensive, probably sucking nodules up from the depths with an apparatus that resembles a huge vacuum cleaner, and it will have unknown environmental impacts.[11]



The largest obstacles to ocean mining may well be political. The U.N. Law of the Sea Conference has thus far failed to produce a treaty that satisfies the 158 member nations, although it has been wrestling with the problem since 1973. In the Third World, mineral-poor nations feel that these resources in international waters should belong to all nations equally, while mineral-rich nations fear that ocean mining may disrupt their export earnings and want to exercise some control over it. And many industrial nations, having developed the technology to mine the seabed, are eager to stake out the claims and begin decreasing their dependence upon mineral exporters. The United States, which imports virtually all its manganese and cobalt, 90 percent of its raw nickel, and one-fifth of its copper, lies adjacent to the world's richest nodule beds and is particularly eager to begin exploiting these resources. Of course, at the prices that will be charged for seabed metals, the United States should still find it economically attractive to recycle most metals.[12]

Historically, a combination of technological advances and cheap energy expanded the reserves of most metals by pushing back the grade of ore that can be mined and processed economically. While there is still room for technological advance, energy has become an ever-tightening constraint. For a while growth will continue: increasing amounts of more expensive energy will be used to mine and process poorer grade ores. But we are approaching a fundamental discontinuity in the *types* of ores available. When traditional ores are exhausted and silicate minerals must be broken down to obtain scarce metals, between 100 and 1,000 times as much energy will generally be required. It is exceedingly doubtful that much metal will be produced in this fashion. Scarce metals are already far more expensive than abundant metals, and the cost differential will become unbearable if

the energy requirements increase 100-fold or more. At that point, society will probably choose to substitute more abundant metals for the more scarce ones—even if this means lower efficiencies.[13]

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Even in the unlikely event that an energy *deus ex machina* makes available such vast amounts of cheap energy that silicate minerals can be mined for scarce metals, the substitution of common metals is still likely to take place. Common metals are far more abundant in rock than are the scarce metals, so in mining for scarce metals vast amounts of common ores will be produced. Rather than accumulating an ever-increasing surplus, society will doubtless find ways to use all the metals produced.

Economic literature is often very glib about the ease of resource substitution. But the desultory results of most recent efforts to substitute other fuels for oil indicate that, even when the need is clear and substitutes are available, the process of change can be slow and painful.[14]

A. G. Chynoweth, Materials Research Director at Bell Laboratories, believes that, as a general rule, "the simpler the application, the easier it is to find a substitute material. If a society's needs are sufficiently simple, the thesis of infinite substitutability might be tenable—materials are likely always to be available for simple products such as utensils for cooking and eating, for clothing, and for simple dwelling structures. But the more a society depends on complex and sophisticated equipment, the more vulnerable it is to scarcities of certain key materials, even if these are used in very modest amounts." To support this point, Chynoweth notes that in the telephone "42 of the 92 elements provided by nature are present as constituents of 35 types of metals and alloys, 14 types of plastic, 12 varieties of adhesives, and 20 different semi-conductor devices."[15]

Some resources are in sufficiently short supply that their primary production is unlikely to contribute much in the not-too-distant future. Oil and natural gas are examples, as are helium, antimony, gold, and molybdenum. For most minerals, however, the most immediate danger is not an absolute global shortage but a supply that is constrained by political, energy, and environmental limits.

"Over the last few years, producers' associations have been formed for copper, bauxite, iron, mercury, and tungsten."

## Other OPECs?



Mineral resources are distributed unevenly. A disproportionate share of the world's most important industrial materials are drawn from southern Africa, East Asia, the Soviet Union, and the western portion of the Americas. Most scholarly work on mineral availability has focused on geological constraints under various economic assumptions. But the single most important lesson of the oil cartel is that political constraints can come first.[16]

Cartels are not a new phenomenon in the field of mineral production. What is new is the growing interest of governments with nationalized firms in the establishment of such collusive associations. Over the last few years, producers' associations have been formed for copper, bauxite, iron, mercury, and tungsten.[17]

The eleven members of the International Bauxite Association control 75 percent of all production—a higher fraction than that of world oil production controlled by the Organization of Petroleum Exporting Countries (OPEC). In 1974, Jamaica increased its taxes on bauxite more than fivefold. All other major bauxite producers in the International Bauxite Association, except Australia, followed suit. Between late 1973 and mid-1974, the price of Moroccan phosphate quadrupled in a series of increases imposed by the Moroccan phosphate monopoly. Price increases by other major producers, including the United States, followed quickly.

The prospects for successful mineral cartels vary from commodity to commodity, depending upon the fraction of the world's resource base controlled by the cartel members, the extent of the fall in demand for the commodity as the price rises, the amount of the commodity produced outside the cartel when the price rises, and the cohesiveness of the commodity association. For many important minerals, the major sources of production are concentrated in a rather small number of hands. (See Table 2.) The current level of concentration implies that a very large number of minerals are vulnerable under this criterion for a successful cartel.[18]

**Table 2: Share of World Production and Reserves of Major Minerals, Four Largest Producing Countries, 1975**

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| Mineral | Production | Reserves | Countries |
|---|---|---|---|
| | (percent) | | |
| Bauxite | 64 | 67 | Australia, Jamaica, Guinea, Surinam |
| Chromium* | 70 | 96 | USSR, S. Africa, Rhodesia, Philippines |
| Cobalt** | 90 | 64 | Zaire, Zambia, Canada, Morocco |
| Copper | 53 | 57 | US, Chile, Canada, USSR |
| Fluorspar | 51 | 42 | Mexico, USSR, Spain, Thailand |
| Gold** | 84 | 88 | S. Africa, Canada, US, Australia |
| Iron Ore | 55 | 61 | USSR, Australia, US, Brazil |
| Lead** | 59 | 77 | US, Australia, Canada, Mexico |
| Manganese** | 78 | 95 | S. Africa, Gabon, Brazil, Australia |
| Mercury | 65 | 65 | Spain, USSR, China, Italy |
| Molybdenum** | 99 | 98 | US, Canada, Chile, Peru |
| Nickel** | 63 | 65 | Canada, New Caledonia*** |
| Phosphate Rock** | 81 | 88 | US, Morocco, Sp. Sahara, Tunisia |
| Platinum group | 99 | 99 | S. Africa, USSR, Canada*** |
| Potash** | 90 | 95 | Canada, W. Germany, US, France |
| Silver | 53 | 60 | Peru, Mexico, Canada, US |
| Tin | 65 | 48 | Malaysia, USSR, Indonesia, Bolivia |
| Vanadium* | 85 | 96 | S. Africa, US, USSR, Chile |
| Zinc | 43 | 57 | Canada, Australia, US, Peru |

*Figures are based on 1974 data. **Calculated for noncommunist countries only.
***For nickel, figures are for two largest producers; for platinum for the three largest.
**Source:** U.S. Bureau of Mines.

In the short run, price increases tend to have little effect on mineral demands. Materials are usually a small part of the cost in most production processes, and firms will choose to pay higher prices for minerals rather than alter their basic production processes. In the long run, it is safe to assume that there is substantial price elasticity for minerals, but this will not stop a cartel from functioning effectively in the interim.



Because it takes a long time to open mines and construct processing facilities, price rises generally will not trigger significant increases in production by non-cartel countries. In those cases where strategic stockpiles are available, however, these will often be tapped in an effort to moderate the impact of soaring prices.

The tension and rivalry that sometimes exists among producers does not mean they cannot form an effective association. Little holds the member countries of OPEC together beyond their keen understanding of their shared self-interest in a cohesive organization. The ownership of many mineral resources by governments rather than by private firms may also strengthen the prospects for successful cartels.

It is sometimes alleged that the ideological differences between major mineral-producing states will handicap the formation of cartels. A quick glance at the list of major producers for several basic minerals underscores this point. However, ideological differences often seem to pale alongside marketplace considerations. For example, the Soviet Union has long cooperated with South Africa to maintain the diamond cartel. Even the United States, which perceives itself as the bastion of international free markets, allows its mineral producers to participate in cartels under the condition that the cartels affect only foreign markets.[19]

If formed at the same time, several cartels can act to one another's mutual benefit. A copper cartel, for example, could be weakened in the short term by the substitution of aluminum for copper. However, the chances of this happening will be greatly reduced if there also exists an effective bauxite cartel that restricts the supply of aluminum.

The likelihood of effective mineral cartels is a matter of conjecture, and reasonable people can come to different conclusions. However, it

is acknowledged by all that such cartels are plausible, and that comprehensive programs to repair, reuse, and recycle our material goods would limit the impact cartels could have on importing countries.



## Energy and Environmental Constraints

More than one-fifth of the total U.S. energy budget is now spent on materials production, and that fraction is rising. The mounting cost of energy and the environmental damage connected with energy and materials production are of increasing concern.[20]

The primary metals industry uses about 8 percent of total energy consumed in the United States. Of this, about two-thirds is used for iron and steel production, and about one-fifth for aluminum. The plastics industry, which remains one of the fastest growing industrial sectors in most Western countries, uses oil as its feedstock. In the United States, more energy is embodied in plastics than is used in aluminum production. Unlike refined metal, however, the energy invested in plastics is generally only recoverable through combustion. In a society where recycling was the rule rather than the exception, the energy initially invested in refining aluminum might be properly perceived as an energy investment for the future. Only 4 percent as much energy is required to recycle aluminum as to refine bauxite ore.[21]

The amount of energy required to produce one unit of a basic material from virgin ore can be compared with the amount required to produce recycled materials from scrap. (See Table 3.) The recycling of aluminum, copper, and polyethylene plastic can save large amounts of energy, while the recycling of glass and newsprint can save smaller amounts.[22]

By producing raw steel from scrap, the steel industry avoids using energy to mine and transport iron ore, coal, and limestone, as well as to produce iron in a blast furnace. In the case of glass production, with only one melting step and no energy-consuming chemical reactions involved, the energy-saving potential from reuse of scrap glass is considerably less.

**Table 3: Energy Used in Processing Virgin and Recycled Materials**

| Material | Energy Needed to Process | | Amount of Energy Saved By Recycling |
|---|---|---|---|
| | Virgin Ore | Recycled Material | |
| | (BTU/pound) | | (percent) |
| Steel | 8,300 | 7,500 (40% scrap) | 10 |
| | | 4,400 (100% scrap) | 47 |
| Aluminum | 134,700 | 5,000 | 96 |
| Aluminum Ingot | 108,000 | 2,200-3,400 | 97 |
| Copper | 25,900 | 1,400-2,900 | 88-95 |
| Glass Containers | 7,800 | 7,200 | 8 |
| Plastics (polyethylene) | 49,500 | 1,350 | 97 |
| Newsprint | 11,400 | 8,800 | 23 |

**Source:** Adapted from Christopher Hill and Charles Overby.

Vast differences exist in the amounts of energy needed to process various virgin ores, but the range of energy requirements for recycling used materials is much narrower. Sometimes energy relationships are even reversed at the recycling stage. For example, 17 times as much energy is needed to refine one pound of aluminum as to manufacture one pound of glass, but almost 50 percent more energy is needed to recycle one pound of glass than to recycle one pound of aluminum. (In fact, at centralized resource recovery plants it can actually require more energy to sort and recover used glass than to simply dispose of the glass and start fresh.) On the other hand, aluminum containers can currently be used only once before being recycled whereas returnable glass bottles can be reused several times at great energy savings.

There is a happy coincidence between conserving energy and making efficient use of material resources. The current wasteful materials policies could only have evolved in an era of cheap, abundant energy. For the last century we have been living off our energy "capital" (sunlight stored in the form of fossil fuels); we must soon begin

living off just our "income" (sunlight used directly). Now that the end of the petroleum era is in sight, fundamental shifts in materials policies will necessarily follow. Even as energy provides a constraint on mineral extraction, a scarcity of materials would limit our future capacity to harness energy. The dependency is mutual.[23]

Materials policies also have important environmental implications. Much of the world's pollution comes from the refining and production of primary materials. This problem can only grow as the mining industry moves to lower grade ores. More energy will be required per unit produced, and all energy use carries an environmental price tag. The mineral processing facility itself, which can discharge dangerous compounds into the air or water, must be outfitted with increasingly sophisticated and costly pollution abatement equipment if continuing degradation is to be avoided.

Biological materials, such as wood pulp and cotton, can also pose environmental problems. Unsound agricultural or silvicultural practices can quickly turn a fertile tract into a disaster area. Because biological resources are renewable, there is a popular tendency to think of them as unlimited. Nothing could be further from the truth. If cultivated carefully, crops can be planted in perpetuity. But if the land is pushed past its carrying capacity or otherwise abused, permanent damage can be done.[24]

As ever-lower grades of ore are mined, the sheer volume of materials to be moved and processed necessarily increases. The mining and transport of this growing tonnage has profound implications for land use. President Ford's ten-year energy development plan—since abandoned by President Carter—would have disturbed more than 45 million acres, an area the size of the state of Missouri. At some point the land required for continued mineral extraction will not be available. As we approach that point, costs will rise rapidly.[25]

Land use problems can arise at the opposite end of the materials cycle as well. After products have been degraded into wastes, they must somehow be disposed of. The situation in the United States illustrates the extent of the problem. Almost one ton of solid waste per

**"Almost one ton of solid waste per person is collected annually from residential, commercial, and institutional sources."**

person is collected annually from residential, commercial, and institutional sources. Most of this waste goes into 14,000 open dumps, occupying about 476,000 acres. At the present rate of disposal, about 500 new dumping locations must be found each year.[26]



The first and most obvious problem is finding land near urban areas for this bulk. Some cities are now looking within a radius of several hundred miles without notable success. The citizens of Virginia Beach, Virginia, in an act of whimsical desperation, decided to pile up 640,000 tons of garbage as a large hill; they then christened it "Mt. Trashmore." Sixty-eight feet high, with a nine-acre base, the grass-covered knoll is the focal point of a recreation area. The 160-acre park in which it sits has a lake, tennis courts, skateboard ramps, an amphitheater, and picnic areas. The city has now announced its intention to build a second such mountain. But this approach has obvious limits.

Not all dumps around the world are as neatly manicured as Mt. Trashmore. More commonly, they are breeding grounds for rats and insects, and prone to trash fires. Incinerator emissions foul the skies; runoff and leachate pollute surface and groundwater. The aesthetic blight is not confined to the dump, but is obvious from the point where materials become wastes: litter and spilled trash mark the route of a problem that grows uglier as it grows larger. With a current U.S. price tag of about $4 billion a year, the problem begs for reduction to a more manageable size.

## Between the Mine and the Dump

Most materials flow directly from their natural source (a mine, forest, or crop) to a processing plant, to a manufacturing industry, to a consumer, and lastly to the dump. At several points along this path, materials can be recycled. It is common, for example, for primary processing industries to immediately recycle the "home scrap" produced inside their own facilities and also the "prompt industrial scrap" produced by manufacturing industries.

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After a manufactured commodity has gone through its expected lifetime, it can often be repaired. This includes such actions as overhauling automobiles, recapping tires, mending clothing, and renovating buildings. A second way to stretch the lifetime of materials is through the direct reuse of material goods without changing their form. Packaging, refillable bottles, and shipping pallets can be immediately reused; functionally adequate, if stylistically dated, automobiles can be resold.

For goods clearly at the end of their usefulness, complete recycling is generally possible. There are large social and economic advantages to segregating them by component materials as close to the point of end use as possible for easy recycling. For example, many neighborhoods, apartment buildings, and commercial establishments provide for the periodic pickup of newspapers and other paper products. Many communities have established recycling centers where paper, beverage containers, and waste oil can be deposited. In a couple of instances—notably, aluminum cans and automobile lubricating oil—the industries themselves have participated in the establishment of recycling centers for segregated products.

Resources can also be recovered at centralized facilities designed to recycle mixed urban wastes. This approach requires the least effort on the part of the individual consumer, but it places vastly greater economic, energy, and environmental demands upon the recycling technology. Moreover, due to the frequent contamination of one set of desired materials by another, mixed-waste systems hold lower potential for a complete recovery of high-grade materials than do other systems.

There are thus three basic components of a sustainable resource policy: waste reduction, with an emphasis upon smaller, simpler, more easily repaired, more durable products; waste separation, which requires consumers to segregate useful constituents of the wastes instead of mixing them together; and waste recovery, which consists of high-technology, centralized facilities to resegregate mixed wastes into their useful components. Each deserves a more careful examination.

## Frugality

A complaint often heard from purchasers of houses, major appliances, or almost anything else today is that "they don't make them the way they used to." As recently as the forties, most products in the industrial world were being built to last. By the end of the fifties, this was undoubtedly no longer true. Many people can empathize with Willy Loman, a character in the play *Death of a Salesman*. "Once in my life I would like to own something outright before it's broken! I'm always in a race with the junkyard! I just finish paying for the car, and it's on its last legs. The refrigerator consumes belts like a goddam maniac. They time those things. They time them so when you've finally paid for them, they're used up."



When something is "used up," it is generally thought of as waste and thrown away. Sometimes it is recognized to contain materials and embodied energy, and it is recycled. But even when an item is recycled, a great part of its value is lost. The difference between the value of the component materials and the price of the item when new is the value added—the labor and overhead costs of manufacturing and selling the product. In order to retain this "value added" for as long as possible as part of the national wealth, society must design its products for durability.

There is no question that most consumer durables could be built to last much longer. Two basic strategies toward this end include designing products for longer wear, and designing them for easy and economical repair or remanufacture. In the latter case, it might be sensible to make even the product's exterior replaceable, so that the item could be kept looking relatively new. This whole approach to materials- and energy-conscious design, known as "non-waste technology," is receiving increasing attention.[27]

During the fifties and sixties, Vance Packard and others thoroughly aired the concept of planned obsolescence. Non-waste technology was definitely not the choice of the day. Packard showed that some products were being specifically engineered, and component materials being explicitly chosen, to ensure a short life span. Some portable

radios, for example, were being designed to last not more than three years and the average life expectancy of several types of light bulbs dropped by about one-third.[28]

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Planned obsolescence is common in many industries. Each year the manufacturers of men's and women's clothing "forecast" which colors they expect to be popular in the coming season. They have a noteworthy record of success: year after year the public purchases the color that is "in." Much of the modern concept of planned obsolescence has its roots, in fact, in the constantly changing styles adopted almost whimsically by the leading manufacturers of men's and women's apparel. Louis Cheskin of the Color Research Institute contends that "most design changes are made not for improving the product either esthetically or functionally, but for making it obsolete."[29]

Henry Ford, the auto titan, based his early success upon a rather simple strategy. He developed a basic design and incorporated it in his Model T; over the course of 15 years he permitted only minor changes in the vehicle and successfully lowered the price from $780 to $290. Competing manufacturers found the price-reduction contest increasingly unattractive. General Motors finally hit on the idea of using stylistic fashionability as the key to selling the consumer a new car. In the event that someone took such good care of his or her automobile that it did not date before its time, annual automobile fashion shows were arranged to prematurely undermine the perceived grace and style of the vehicle.[30]

Marketers also discovered that by "positioning" their products carefully they could promote multiple purchases. Appliance manufacturers, for example, began narrowing the range of tasks that could be performed with a single utensil. Whereas a few years ago most people bought pots and pans for their kitchens, today they are sold appliances that can cook only hot dogs, or only hamburgers, or only doughnuts. In the process, kitchen cupboards must be enlarged to accommodate cookware that is used rarely, at best.

Differences in "position" are almost invariably the creation of advertising executives rather than the result of any real need on the part of

**"In 1977, Americans used some 20 billion square feet of aluminum foil and 24 billion aluminum cans."**

a particular consumer. Cigarettes and alcoholic beverages are two of the most carefully "positioned" products in the advertising field. One brand of Scotch whiskey will sell for double the price of another —despite virtually identical tastes—simply because it is marketed as the choice of the rich. The real difference, of course, is not in the product but in the packaging. Given this economic fact of life, the packaging industry has become a growth industry *par excellence*.



Packaging represents one of the fastest growing materials-using sectors in the economy. A number of nondurable, small consumer goods are deliberately marketed as "throwaways." Beverage containers and convenience foods are prominent examples. Everything from popcorn to complete meals can be purchased in aluminum pans designed to be tossed away after one use.

These examples may seem trivial, and, taken individually, they are not in fact very important. But when added up, the packaging problem becomes formidable. In 1977, Americans used some 20 billion square feet of aluminum foil and 24 billion aluminum cans. Virtually all the foil and 18 billion cans became part of the nation's solid waste immediately after use.[31]

In the United States, packaging now accounts for between 30 and 40 percent of municipal solid waste. About 75 percent of all glass produced, 40 percent of the paper, 29 percent of the plastic, 14 percent of the aluminum, and 8 percent of the steel is used in packages. In many cases, the growth in packaging far outstrips the growth in sales of the product being packaged. Between 1958 and 1970, milk consumption per capita decreased by 23.1 percent while milk containers increased by 26.1 percent per capita. Further, Americans sometimes pay several times more for containers than for the products inside them: salt in small throwaway containers can cost 15 to 17 times as much as the same salt purchased in larger containers.[32]

Within limits, there are technological ways to address the problems of wastage in packaging. With a modest amount of redesigning for materials conservation, many products could do more with less. The Campbell Soup Company, for example, is now marketing a new can

for dog food that uses 30 percent less materials, and costs 36 percent less to manufacture, than previous cans. If all current steel and tin cans were replaced with cans of the Campbell design, one million tons of these metals would be saved annually.[33]



But to design a society that is truly thrifty in its use of materials, far more than technological fixes will be required. At a minimum, products must be built to last and be designed in ways that simplify repairs and remanufacturing.

In remanufacturing, many identical products are brought to a central facility, disassembled, cleaned, inspected, and then reassembled, usually on an assembly line. This is a common procedure with automobile parts and even tires. About one-fifth of all vehicle tires produced in the United States today are retreaded. These 45 million retreads have lifetimes up to 90 percent as long as those of new tires. If all tires were retreaded once, the demand for synthetic rubber would be cut by about one-third, tire disposal problems would be cut in half, and substantial energy savings would be realized. Jobs would be lost in the synthetic rubber and new tire industries, but new jobs would be created in the tire recapping business. Such businesses tend to be much smaller and more regionally distributed than facilities to manufacture new tires.[34]

The renovation of dilapidated urban residences, currently inspired in part by rising gasoline costs for commuters, can be thought of as an important form of repairing obsolete existing products. Often these structures were constructed more soundly than many contemporary buildings. If during renovation they were also weatherized and—where possible—outfitted to take advantage of solar energy, the energy benefits would be substantial. No new materials need be constructed for the shell of the building, and a considerable amount of transportation fuel would be saved as well by former commuters. In the Third World, upgrading existing domiciles has been found to be far more cost-effective than constructing new houses. As a consequence, the World Bank has shifted much of its housing assistance from new construction to rehabilitation, and has spent $866 million on such projects since 1972.[35]

Of the various "solutions" to the problem of materials scarcity, none is more important than waste reduction. Eliminating things that are unnecessary is better from every perspective than simply recycling them: waste reduction saves materials, reduces energy demands, eases environmental problems, and eliminates some of the clutter in contemporary life in the industrial world. There are already indications of trends in this direction. In many subcultures in Western societies, the ethic of conspicuous consumption is being replaced by one of conspicuous frugality. Carried to its logical conclusion, a careful examination of waste reduction will require a fundamental rethinking of the structure and direction of the global economy.[36]



**Waste Separation**

No matter how heroic an effort is made to reduce the volume of materials leaving the economy each year, a large amount of waste will still be generated. In general, the most cost-effective and efficient way to reintroduce such materials into productive use is through segregation at the point of origin. Much of the energy invested in economic production is used to refine and bring structure to what was originally a disorganized conglomeration of raw materials. It seldom makes sense to mix these diverse materials together in a garbage stream, only to be forced to invest still more energy later in their resegregation.

Many governments have begun to promote recycling through source separation. The motivations behind these efforts vary. The United Kingdom and France, for example, cite their declining domestic self-reliance for minerals and view recycling as a path toward more material independence. Sweden has an aggressive paper recycling program to reduce tree cutting since forest products are a mainstay of the Swedish economy. The Netherlands has noted the potential energy savings associated with recycling when compared with the refining of primary ores. And, of course, all are acutely aware of the need to reduce the volume of waste to be disposed of.[37]

Source separation is the best way to recover wastepaper for recycling, since paper is frequently contaminated when mixed with other gar-

bage. It is also an attractive way to recycle glass, aluminum, ferrous metals, some plastics, and organic wastes for composting. At least 500 source separation programs of various types now operate in the United States. In Portland, Oregon, a city of 900,000 people, an estimated equivalent of 80 full-time employees recycle 77 tons of urban refuse daily.[38]

In Sweden, the separation of wastepaper from all other garbage in homes, shops, and offices will be required by law for most of the country by 1980. The paper industry made such legislation a condition of its investments in new wastepaper processing plants. In the United States, about one-fifth of all paper is recycled, and it accounts for 90 percent (by weight) of all materials recycled. Recycling of high-grade paper is required by law in all federal office buildings with 100 or more employees; newspaper recycling is stipulated for federal facilities housing 500 or more families; and recycling of corrugated containers is mandatory in federal facilities using ten tons or more of such materials per month.[39]

Glass recycling has received a high priority in many countries because it can help solve a serious litter problem. The benefits of recycling glass are not as great as the benefits of reusing glass containers whenever that is possible—and generally it is possible. But recycling glass does make great sense when reuse is not an option. West Germany uses 3,000 collection containers to recycle 260,000 tons of used glass a year—equaling about 10 percent of the country's annual production of glass containers. In Switzerland, one large glass manufacturing concern has been consuming increasing amounts of recycled glass each year: 16,471 tons in 1973; 45,800 tons in 1974; 55,696 tons in 1975; and 62,684 tons in 1976. Sixty percent of the Swiss population now recycles glass.[40]

A classic success story of glass recycling involves the Glass Containers Corporation facility in Dayville, Connecticut, which found that it could reduce particulate emissions by increasing its use of recycled glass. Under pressure from the Environmental Protection Agency to introduce pollution control measures, the plant began increasing its use of cullet. Today, a full 50 percent of its raw materials comes from recycled glass—70,000 tons a year—and the plant manager hopes to

**"In the United States, about one-fifth of all paper is recycled."**

increase the percentage. The facility now meets air quality standards without costly scrubbers, conserves fuel, produces a high quality glass, reduces both litter volume and landfill requirements, and pours $2.5 million into the local economy for recycled glass.[41]



The benefits of metals recycling are even more apparent. In addition to the energy savings discussed earlier, the reuse of ferrous scrap by steel mills and foundries leads to an 86 percent reduction in air pollution, a 76 percent reduction in water pollution, a 40 percent reduction in water use, and a virtual elimination of solid wastes. Similar benefits are involved in the recycling of other metals.[42]

Essentially all metal embodied in heavy industrial machinery is recycled. But the record for consumer products is less impressive. Herschel Cutler of the Institute of Scrap Iron and Steel points out that "there are over 600 million tons of recoverable ferrous scrap strewn around [the United States], and better than 8 million cars, buses, and trucks will be added to the backlog this year." In 1977, post-consumer recycling contributed 20.1 percent of American copper (down from 24.8 percent in 1968), 19.2 percent of iron and steel (up from 13.3 percent), and 8.4 percent of aluminum (up from just 4.6 percent nine years earlier). About half of all antimony entering the U.S. economy is recycled—mostly from antimonial lead in batteries.[43]

Although aluminum is worth several times more per ton in the marketplace than ferrous metals, iron and steel are much more easily recycled as they can be separated from other materials with magnets. While technological advances might make centralized separation of nonferrous metals practical, the real future of recycled aluminum will probably depend upon source separation.

Plastics can be divided into two main classes: thermoplastics, such as polyethylene, polystyrene, and nylon; and thermosets, such as polyesters, phenolics, and epoxies. Thermoplastics can be recycled by remelting, though some quality is lost on each new round. Such remelting requires a small fraction of the energy originally needed to make the plastic. Plastics must be carefully separated by chemical type and all contaminants must be removed before melting. Unlike mixed steels, mixed plastics do not form alloys well, if at all. Only industrial

scrap is currently recycled; post-consumer plastic is, at best, burned as fuel.

28 Thermoset plastics, however, cannot be remelted. When heated, they break down into mixed organic gases and liquids. It is possible that these organic products could be used as chemical feedstocks, but it is also possible that the only potential use for waste thermoset plastics is as a fuel.

The biological portion of the solid-waste stream is perhaps the simplest to recycle. Consisting of paper, garden debris, and various food-related materials, this portion can be easily separated in individual households, and then decomposed in a compost pile. Composting is a very simple process, practiced by farmers and home-gardeners for centuries, and it requires little sophisticated technology. The organisms necessary for decomposition are normally already present; the materials to be composted only need to be kept in an oxygen-rich environment through occasional mixing. Within a period of weeks, a compost is produced that is odorless and germ-free, rich in nutrients, and useful as a fertilizer and soil conditioner. Composting can be done either at the household level for use on private gardens or at centralized facilities for commercial application on croplands, woodlands, or strip mined areas.

Interest in composting has been building rapidly around the world in recent years. In Leicester, England, the Wanlip Composting Plant is simultaneously treating domestic garbage and municipal sewage sludge. The resulting compost is sold for use on croplands and on household gardens. In New York's South Bronx, a composting program begun in 1976 aims to restore the soil on 500 acres of vacant urban land. The main input consists of vegetable wastes from a large produce market that previously were hauled to a landfill at considerable cost. In the first year of operation, the Bronx Frontier Development Corporation was able to restore 17 acres of vacant land with a six-inch layer of compost. Each fertilized acre should be able to supply vegetables for 40 or more people.[44]

The biggest disadvantage of source separation schemes is that they are small enterprises that can be wildly buffeted by the dramatic price

"In many cities, expenditures on waste management are second only to those on education."

changes that often occur in raw materials markets. Macroeconomic trends affect the prices not just of recycled materials, but also of raw materials. Most of the world's mineral companies are either huge, transnational enterprises or government-owned firms; in either case, they are able to tighten their belts and wait out tight periods. Community recycling centers do not, unfortunately, have such flexibility.



One answer might be government ownership or underwriting of recycling efforts. This, however, seems likely to dampen some of the entrepreneurial spirit so pervasive in the recycling field. Another option would be to provide government price supports, or guaranteed government markets, for recycled goods, thus flattening out the hills and valleys in materials prices. Germany, Denmark, and the Netherlands all have programs to encourage government procurement of recycled paper in an effort to ensure at least a minimum level of demand.[45]

Direct subsidies are another possibility. Americans spend about $4 billion a year collecting and disposing of municipal solid wastes. In many cities, expenditures on waste management are second only to those on education. To the extent that this volume can be significantly reduced by active source separation and recycling programs, a credit should be received by the recycler for the money saved. Today, only about 6 percent of municipal solid waste is recovered in any form.[46]

In the final analysis, the success of source separation programs depends on the percentage of the public that participates in them. On the one hand, thorough programs with concomitant life-style changes could result in a more dramatic increase in the percentage of goods recycled. On the other hand, strenuous programs might mean fewer people will take the trouble to participate—either to acquire materials or to dispose of wastes—except in times of national crisis or in the event of major price increases.

Most of the recycling efforts around the world during the last few years have attracted widespread participation. In the central Swedish town of Orebro, for example, between 80 and 90 percent of households were willing to cooperate with fairly aggressive experimental recycling efforts. Writing in *New Scientist*, Brian Hammond contends

that "the reasons are not difficult to define. In an increasingly impersonal world, in which political and economic events seem as arbitrary and unalterable as the weather, many of us feel remote from the real levers of power. At the individual level, recycling systems give us the chance to help, to exercise control over at least one section of the whole complex and bewildering macroeconomy. We become, once more, a useful part of the whole set-up—and we like it."[47]



The role that source separation could play is often underestimated by government officials and others who believe that people simply will not change their behavior. Yet people change their behavior all the time, and at least occasionally it is for the better. A study in the United States suggested that an average family would only need to spend about 16 minutes a week to be involved in a source separation program. It is hard to believe that even rather modest changes in prices, coupled with a reasonable effort at public education, couldn't bring about at least that level of participation.[48]

## Resource Recovery

It is unlikely that urban waste streams can be entirely recycled through source separation. Some centralized facilities will probably prove necessary, especially near large metropolitan areas. The U.S. Environmental Protection Agency, in its annual report to Congress for 1977, listed 118 centralized resource recovery facilities in various stages of development. About half of these had a capacity of at least 1,000 tons of refuse per day.[49]

Resource recovery systems remove valuable materials by taking advantage of their physical properties. Copper, for example, has a specific gravity of 8.9 and can thus be separated from aluminum (with a specific gravity of 2.7) using a liquid medium. It can be separated from iron using magnets. Its color allows it to be separated from bronzes and brasses using optical techniques. Sophisticated techniques are being developed to separate copper from other nonmagnetic materials such as tin, lead, paper, and polymers.[50]

At today's prices, energy production provides two-thirds or more of the revenue from centralized resource recovery systems, while materials recovery provides less than one-third. The tendency is to establish a diversity of smaller resource recovery plants near the sources of energy demand, at shopping centers and factories, for example. However, there are very real social and political barriers to the establishment of such units in most neighborhoods.[51]

One objection stems from the volume of traffic involved. A 2,000-tons-per-day resource recovery facility would receive about 250 large truckloads daily. Other objections at the local level deal mainly with environmental problems: biological pathogens common in garbage, heavy metals and complex hydrocarbons emitted during combustion or pyrolysis, water pollution from landfills in which the residues are buried, and local fogging due to moisture discharges from cooling towers. Because the extent of risk is not yet clearly understood, there is a general reluctance to build resource recovery units that might be the target of environmental legislation adopted at some later date.[52]

Three principal energy-harnessing technologies are commonly regarded as holding the most potential for resource recovery systems: waterwall incineration, refuse-derived fuel, and pyrolysis. Waterwall incineration to produce steam—widely practiced in Europe—is a mature technology, although new approaches may be able to increase the efficiency of boilers. "Refuse-derived fuel" is produced by grinding (and sometimes chemically treating) the organic components of urban waste. The highly combustible product can be mixed with fossil fuels in conventional power plants. Pyrolysis—a technology to convert wastes into high-quality liquid, gaseous, and solid fuels—is not yet being used successfully on a commercial scale.[53]

As the process becomes more sophisticated, the possibility of mechanical problems increases. Pyrolysis plants, in particular, have been plagued with malfunctions. Moreover, although more sophisticated processes produce a higher quality energy, they do so at a substantial net energy penalty. It may well be that the optimal energy-harnessing option for urban wastes is direct combustion, perhaps using fluidized beds for greater efficiencies. Virtually all resource recovery facilities recover ferrous metals, and some employ equipment (with varying

levels of success) to separate other metals and glass from the combustible garbage. The economics are most viable when conventional disposal costs are high and markets for recycled materials are nearby.



A fourth approach to energy production from waste, which shows particular promise for metropolitan areas with populations over 500,000, is anaerobic digestion of a mixture of municipal organic waste and human sewage. The by-products are methane, which can be fed into existing natural gas pipelines, and a rich residue that can be used as fertilizer. The principal problem is avoiding contaminants that could poison the digestion process or that could pose hazards when applied in fertilizer. Also, because this is a relatively slow process, the facility would require more land area than would be needed by other centralized technologies.[54]

Leningrad, with a population of 4.3 million, expects to process all its municipal solid wastes through a huge resource recovery plant by 1985. The proposed plant would be six times larger than the existing 580,000-tons-per-year facility. The Soviet facility benefits from the fact that Russian municipal wastes contain almost no plastic and very little packaging. Most paper is separated at the point of origin for recycling; glass containers are refillable, require large deposits, and have a high rate of return.[55]

In Toyohashi, Japan, a city with a population of 300,000, an "Urban and Rural Environmental Combination System" is being constructed. With a projected cost of $40 million, the system should be completed by 1980. Heat recovered from an incineration plant and compost from an associated composting plant will both be used in a huge greenhouse constructed on the site.[56]

In several countries, a strong rivalry has developed between the advocates of source separation and the champions of centralized resource recovery facilities. The latter tend to believe the former have laudable ideals, but that their proposals are little more than naive distractions from the real solutions. Source separation is fine as far as it goes, according to the resource recovery school of thought, but it doesn't go very far because people just won't change their life-styles.

Proponents of source separation, on the other hand, feel that centralized facilities are capital-intensive behemoths that produce little net energy and recover a comparatively small fraction of the material value of trash. Resource recovery centers are viewed by this group as marginally better than landfills as a destination for whatever is not successfully recovered through source separation. But there is a strong fear that economies of scale will dictate that huge units be built at high expense to handle the entire current volume of urban waste. Afterward, cities would have a strong vested interest in maintaining the same level of waste in order to maximize the return on their sunk investments. This could lead to official discouragement—or even forbidding—of community recycling schemes.[57]



This scenario is entirely plausible. Successful source reduction efforts, coupled with successful programs to segregate the remaining wastes at the point of origin, could financially cripple a centralized recovery facility. A more sensible approach would be to first see how much of the problem could be solved by comprehensive programs for reducing waste, recycling, and composting. Appropriately-scaled resource recovery facilities could then be constructed to process the remaining wastes.

## Making the Most of What We've Got

The intellectual case for materials conservation is powerful, and the needed technology is not terribly sophisticated. The missing ingredients are a broad social commitment to this goal and the implementation of specific policies to achieve it. A large number of specific policies have been suggested, and a few have been enacted in various places.

An intelligent starting point would be the elimination of the discriminatory taxes and regulations that currently place secondary materials in an uncompetitive position. Depletion allowances, for example, constitute an outright subsidy designed to encourage the consumption of virgin materials. In the United States, railroad rates are lower

for ores than for secondary materials. Moreover, waste disposal costs are not generally felt directly by the consumer, and they frequently do not include all environmental costs. The policies that were enacted in a period of bountiful resources deserve a comprehensive reexamination today.[58]

Perhaps the most highly publicized scheme to combat solid waste deals with one of the most visible waste products—the beverage container. Some analysts favor deposits on bottles and cans, while others would ban nonrefillable containers altogether. Sweden and Norway have taxation and deposit programs for beverage containers. Denmark prohibits the use of nonreturnable soft drink containers and is studying the concept of requiring a standard-sized bottle for many different beverages. Such an easily reused bottle is already marketed in Denmark for wines.[59]

An analysis by the U.S. Environmental Protection Agency of proposed national returnable-bottle legislation found that a successful program would reduce roadside beverage-container litter by 60 to 70 percent by 1980, and would save 500,000 tons of aluminum, 1.5 million tons of steel, and 5.2 million tons of glass each year. It would also save the energy-equivalent of 45.6 million barrels of oil annually and require no more capital investment than a one-way container system would. The program would produce 165,000 jobs while eliminating 80,000 jobs (of which normal attrition would account for 40,000, in any case). And the use of returnable beverage containers would save consumers $2.5 billion annually by 1980, rising to savings of $3.2 billion a year by 1985.[60]

Although returnable beverage containers would be of enormous benefit to society, practical politics is always biased toward the status quo. For example, the 40,000 people who would lose jobs if all bottles had to be returnable have a clear idea who they are; the 165,000 people who would acquire jobs are not easily identified, and have no union looking out for their prospective interests. Moreover, a returnable beverage container law would cut into the profits and growth potential of manufacturers of bottles and cans alike, and the two have forged a potent political alliance to defeat such legislation. The problem, in this case, lies not so much in determining what policies would

**"Returnable beverage containers would save consumers $2.5 billion annually by 1980, rising to savings of $3.2 billion by 1985."**

promote the public interest as in assembling the political muscle to overcome the opposition of those to whom change would not necessarily represent an improvement.



In addition to mandatory deposits for beverage containers, such deposits have been proposed for automobiles, tires, electrical machinery, and consumer durables. In Sweden, everyone who has purchased a car since 1976 has had to pay a $54 deposit; when the car is scrapped, the owner receives a refund of $65. The average life expectancy of a Swedish car is about 9 years. When the car is returned to a certified scrap yard, the owner receives a certificate, which must in turn be shown to the relevant ministry in order to "deregister" the automobile. In lieu of such deregistration, the owner is presumed to maintain ownership of the vehicle, and must continue paying annual registration taxes on it in perpetuity.[61]

Another common proposal is that all products be charged a flat tax based upon the amount of virgin material they contain. The tax could be based on the cost to society of toxic emissions and other pollutants, land loss, resource depletion, and the disposal of the material after use. A study by the Research Triangle Institute concluded that the 18 to 20 percent of U.S. paper currently recycled could be doubled to 36 percent—roughly the percentage recycled during World War II—by 1985 if a $25-per-ton product charge were introduced gradually. The net social benefits were calculated at $1 billion for a ten-year period. Similar charges could be levied for all the principal sources of waste.[62]

A number of British analysts have suggested the use of an amortization tax that would be proportionate to the estimated life of a product—from 100 percent for products expected to last a year or less down to nothing for those designed to last 100 years or more. The obvious effect of this scheme would be to penalize short-lived products in the marketplace. The use of severance taxes has been proposed by economist Talbot Page. This is simply a levy on virgin material as it is extracted from the ground, based either upon its monetary value or on the quantity of the material extracted. The severance tax would be almost a mirror image of depletion allowances, and its purpose would be to slow down the rate of extraction.[63]

A most important additional role for government at all levels would be to facilitate and stabilize markets for secondary materials, perhaps by providing price supports or even by becoming the purchaser of last resort. An increase in the product charges on virgin ore might also be necessary when the price drops due to ordinary market fluctuations. Building a stable market for secondary materials will doubtless be a long process, requiring the generation of enthusiasm for recycled materials in the manufacturing sector and the creation of an infrastructure to handle the processing.

While some combination of taxes, incentives, and subsidies should provide a context within which a materials-conserving ethic would evolve, a major program of public education will doubtless also be necessary. This is particularly true for life-style changes to reduce the volume of materials used, and for programs to segregate household wastes at the point of origin. Cooperation in such programs cannot simply be legislated; broad public support is required.[64]

If source separation is to be truly successful in individual homes, modest design rearrangements might be necessary. Segregated places for cans, bottles, paper, and food scraps could handily take the place of the single garbage can. There will, of course, be some costs connected with these changes, but they are trifling when compared, for example, with the cost of indoor lavoratories and the connecting sewage systems—an expensive "waste-disposal technology" that was unheard of a century ago but that is now almost universal in the industrial world. Twenty years from now, it may be as unusual to build a house without segregated waste receptacles as it would be now to build a house without indoor plumbing. Garbage trucks would be similarly partitioned to keep collected materials apart.[65]

For commercial buildings and multifamily dwellings, the government may need to assist the establishment of recycling programs. Today, for example, most local governments have policies requiring a certain amount of parking space per building. Considering the extraordinary advantages of source separation, it would be sensible for these same governments to set mandatory space requirements for on-site processing and storage of recyclable materials.

Much of the contemporary world was built in an era when oil cost $2 per barrel and most resources were plentiful. We are now approaching an era in which oil will cost $20 per barrel and several resources will begin to grow scarce. This will necessarily prompt some changes in the way we do things, and perhaps some changes in the choice of things we do.



In some cases, these changes will involve no more than the substitution of intelligence for materials. New approaches to old problems will yield solutions that require materials to perform a different function. For example, adhesives can be substituted for nuts and bolts in joining two materials together. Telecommunications can be substituted for mail as a means of transmitting information. A sophisticated mini-calculator can perform functions that previously required a good-sized computer. In each of these instances, the substitution results in a significant decrease in both the materials and the amount of energy required to perform a specific function.

To the extent that life-style changes are required, the public seems willing to embrace them. Louis Harris concluded from a 1975 poll that "when the alternative is posed between changing our life-style to have less consumption of physical goods, on the one hand, and enduring the risks of continuing inflation and unemployment on the other, by 77 percent to 8 percent, the American people opt for a change in life-style." Particularly impressive was the willingness to abandon frequent changes for style reasons alone. Ninety-two percent were willing to eliminate annual model changes in automobiles, and 90 percent, yearly fashion changes in clothing. A 1977 poll disclosed that 76 percent of Americans favored "learning to get our pleasure out of non-material experiences" rather than "satisfying our needs for more goods and services." Eighty-two percent preferred to "improve those modes of travel we already have" instead of "developing ways to get more places faster."[66]

The public may be ahead of its leaders in recognizing that we are entering a new era in which thrift will be a prime asset, and that this development holds more promises than threats. Materialism has failed to provide something for which people hunger, and increasingly they are turning elsewhere. Voluntary simplicity—a central message of

every major religious figure from Jesus to Lao-Tzu, from Buddha to Muhammed—is finally acquiring a modern following. And in that fact may lie one of the principal hopes of those who wish to build a sustainable world.[67]

What would a sustainable world look like? Material well-being would almost certainly be indexed by the quality of the existing inventory of goods, rather than by the rate of physical turnover. Planned obsolescence would be eliminated. Excessive consumption and waste would become causes for embarrassment, rather than symbols of prestige.

The environment would be enhanced, and global population would be balanced with the planet's carrying capacity. All people would have a means of livelihood that yielded fair wages and did not deprive them of health or pride. The inflationary impact of raw materials prices would be diminished, as resource scarcity was mitigated by the widespread use of durable products that could be recycled. Industries and energy sources would be decentralized and hence less vulnerable to acts of man and nature. Both ends of the material chain—the mine and the dump—would fade in importance compared with the improvement of the human condition from existing material stocks. Society would, at long last, apply its collective intellect and energy to the central task of an intelligent materials policy: making the most of what we already have.

## Notes

1. A resource recovery rate of two-thirds is probably a conservative figure. The Environmental Protection Agency's *Fourth Resource Recovery and Waste Reduction Report to Congress* (Washington, D.C.: 1977) estimates that resource recovery facilities in all urban areas could reclaim 56 percent of the nation's solid waste. If just 30 percent of the nonmetropolitan solid waste could be reclaimed through source separation, the two-thirds figure would be realized. A real social commitment to waste separation at the point of origin could lead to higher recovery rates. Neil Seldman, in "Economic Feasibility of Recycling," Report to the Program Development and Human Resources Division, Office of Technical Assistance, Economic Development Administration, U.S. Department of Commerce, June 30, 1978, argues that 80 percent of our wastes might be recovered with existing technology.



2. NATO Scientific Affairs Division, *Rational Use of Potentially Scarce Metals* (Brussels: North Atlantic Treaty Organization, 1976).

3. The per capita figure includes iron, copper, aluminum, cement, and fossil fuels; Brian Skinner, "A Second Iron Age Ahead?," *American Scientist*, May/June 1976; Thomas Quinby, *Recycling: The Alternative to Disposal* (Baltimore: Johns Hopkins University Press, for Resources for the Future, 1975).

4. Sherif Mahmoud el Hakim, "Social Policy and the Environmental Issue: The Case of Cairo's Domestic Waste," presented to the Conference on Social Policy in Arab Countries of the Euro-Arab Social Research Group, Malta, November 21-28, 1976.

5. Skinner, "A Second Iron Age Ahead?"; the Environment Protection Agency's *Fourth Report to Congress* contains several illustrative examples of policies that discriminate against recycled materials.

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7. Allen Hammond, "Alcohol: A Brazilian Answer to the Energy Crisis," *Science*, February 11, 1977.

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12. Elizabeth Mann Borgese, "A Ten-Year Struggle for Law of the Sea," *The Center Magazine*, May/June 1977; Richard Hudson, "The International Struggle for a Law of the Sea," *Bulletin of the Atomic Scientists*, December 1977.

13. Committee on Mineral Technology of the National Research Council, *Technological Innovation and Forces for Change in the Mineral Industry* (Washington, D.C.: National Academy of Sciences, 1978); Skinner, "A Second Iron Age Ahead?"

14. National Commission on Supplies and Shortages, *Government and the Nation's Resources*, Washington, D.C., December 1976, for example, notes both that tungsten can be substituted for molybdenum in tool steel and that molybdenum can be substituted for tungsten. They are, in fact, mutually substitutable, but there are no other satisfactory substitutes. The optimist's case for materials substitution is summed up in H. E. Goeller and Alvin Weinberg, "The Age of Substitutability," *Science*, February 20, 1976; the pessimist's case is argued in Charles Park, *Earthbound* (San Francisco: Freeman-Cooper, 1975).

15. A. G. Chynoweth, "Electronic Materials: Functional Substitutions," in Philip Abelson and Allen Hammond, eds., *Materials: Renewable and Nonrenewable Resources* (Washington, D.C.: American Association for the Advancement of Science, 1976).

16. E. R. Fried, "International Trade in Raw Materials: Myths and Realities," *Science*, February 20, 1976.

17. P. O. Eckbo, *OPEC and the Experience of the Previous International Commodity Cartels*, Energy Laboratory Working Paper, Massachusetts Institute of Technology, Cambridge, Mass., August 1975; Charles Johnson, "Cartels in Minerals and Metal Supply," *Mining Congress Journal*, January 1976.

18. John Tilton, *The Future of Nonfuel Minerals* (Washington, D.C.: The Brookings Institution, 1977).

**19.** Under the Webb-Pomerene Act, U.S. companies are allowed to participate in cartels as long as American markets are not adversely affected.

**20.** Earl Hayes, "Energy Implications of Material Processing," in Abelson and Hammond, *Materials: Renewable and Nonrenewable Resources.*



**21.** Battelle Columbus Laboratories for the Bureau of Mines, *Energy Use Patterns in Metallurgical and Non-Metallic Mineral Processing, 1975-76* (a series of reports) (Springfield, Va.: National Technical Information Service, various dates).

**22.** This table is indicative but not precise. The actual numbers will vary slightly depending on the method of accounting used to obtain the numbers and the way energy units of different quality are treated.

**23.** Preston Cloud, "Mineral Raw Materials and the National Welfare," in U.S. Congress, Joint Economic Committee, *U.S. Economic Growth from 1976-1986: Prospects, Problems, and Patterns, Volume 4,* Hearings, November 16, 1976.

**24.** Erik Eckholm, *Losing Ground: Environmental Stress and World Food Prospects* (New York: W. W. Norton & Co., 1976); Lester R. Brown, *The Twenty-Ninth Day: Accommodating Human Needs and Numbers to the Earth's Resources* (New York: W. W. Norton & Co., 1978); Lars Kardell, "Ecological Aspects of the Swedish Search for More Wood," *Ambio,* Vol. 7, No. 3, 1978.

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**27.** A. H. Purcell, "Principles and Creation of Non-Waste Technology (NWT) and Production," *Resources Policy,* March 1977; Robert Lund, "Making Products Live Longer," *Technology Review,* January 1977.

**28.** Vance Packard, *The Wastemakers* (New York: David McKay Company, Inc., 1960)

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35. Bruce Hannon *et al.*, "Energy Use for Building Construction," Center for Advanced Computation, Paper 228, University of Illinois, Urbana, Illinois, February 1977; Richard Stein, *Architecture and Energy* (Garden City, N.J.: Anchor Press/Doubleday, 1977); Bruce Stokes, *Local Responses to Global Problems: A Key to Meeting Basic Human Needs* (Washington, D.C.: Worldwatch Institute, February 1978).

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**39.** Bidwell and Raymond, "Resource Recovery in Europe"; an excellent overview of Swedish recycling programs is Olov bon Heidenstam, "Swedish Experience in Separation at Source," *Solid Wastes*, July 1977; Environmental Protection Agency, *Fourth Report to Congress.*

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**41.** Larry Kramer, "Bottle Maker Cuts Costs, Pollution with Oil Glass," *Washington Post*, July 2, 1978.

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**47.** Brian Hammond, "Recycling Begins at Home," *New Scientist*, July 17, 1975.

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51. Hill and Overby, "Improving Energy Productivity."

52. An excellent two-part survey of potential environmental problems and possible solutions is Allen Serper, "Anticipation of Environmental Impacts of Facilities Urged," *Solid Wastes Management*, February and March 1978.

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**59.** Bidwell and Raymond, "Resource Recovery in Europe"; "Denmark Tightens Legislation on Waste Collection and Recycling," *World Environment Report*, May 8, 1978.

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**62.** A. K. Miedema *et al., The Case for Virgin Material Charges: A Theoretical and Empirical Evaluation in the Paper Industry* (Research Triangle Park, N.C.: Research Triangle Institute, January 1976).

**63.** "A Blueprint for Survival," *The Ecologist*, January 1972; Page, *Conservation and Economic Efficiency.*

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**65.** Such units would probably have some form of compacting capability. Trash compactors, as currently used, are probably a step backward from an intelligent materials program: they mash all sorts of diverse materials together, making recycling appreciably more difficult. However, if compactors were used for different materials as part of a comprehensive source separation effort, they would significantly reduce the amount of space required for materials storage. Beverage cans provide one index of the effect of compacting: a cubic yard of uncompacted cans weighs about 300 pounds; a cubic yard of compacted cans weighs over six tons. Arsen Darmay and William Franklin, *The Role of Packaging in Solid Waste Management: 1966-1976* (Washington, D.C.: Government Printing Office, 1976).

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DENIS HAYES is a Senior Researcher with Worldwatch Institute and author of *Rays of Hope: The Transition to a Post-Petroleum World* (W. W. Norton, 1977). His research encompasses alternative global energy strategies, energy conservation, nuclear proliferation, and, most recently, policies that will create a sustainable society.